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# Simultaneously Compression of the Passively Mode-Locked Pulsewidth and Pulse Train

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Abstract

Simultaneously compression of the passively mode-locked pulsewidth and pulse train have achieved by using a plano-convex unstable resonator hybrided by a nonlinear Sagnac ring interferometer. The >30mJ single pulse energy of alone oscillator and <10ps pulsewidth have obtained. Using this system, the LAGEOS and ETALON satellites laser ranging have been performed successfully.

Key words: Nonlinear Sagnac ring interfereometer,
Simultaneously compression of M-L pulsewidth and train

## 1. Introduction

In a variety of scientific research and technical applications, laser ranging included, the single mode-locked pulse is necessary. For this reason, the single pulse selector has to be need, and perhaps needs several stages amplifiers in order that achieving necessary energy. Moreover, in outfield applications, not only need smaller and lighter equipments, but need that, the equipment insensitive to mechanical and thermal perturbations, maintaining good aligament over days of operation. Recently years, our group in base on *investigations* of antiresonant ring hybrided unstable resonator, deeply into investigated the conditions and paramaters of simultaneously compression using an unstable resonator hybrided by nonlinear ring interferometer, and following results have been obtained:
the pulse train compressed to two cavity periods, the mode-locked pulsewidth

compressed to $<$10ps, the single pulse energy ( alone oscillator ) $>$30mJ (Nd:YAG), the weight and size of the setup (not including power supply) 32Kg and $72\times30\times24Cm^3$ respectively.

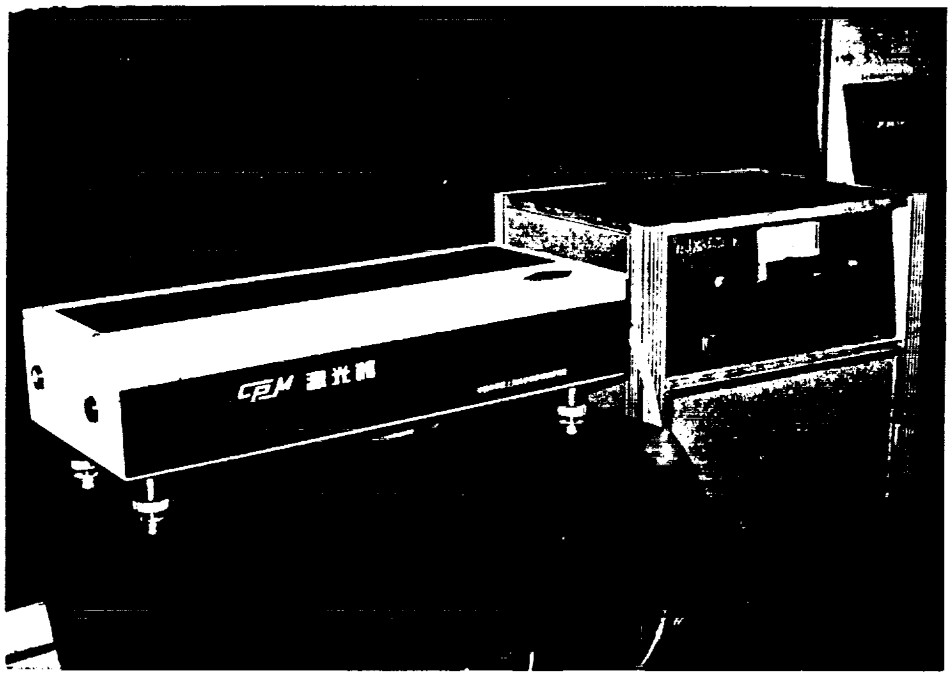

Fig.1 Photograph of the setup

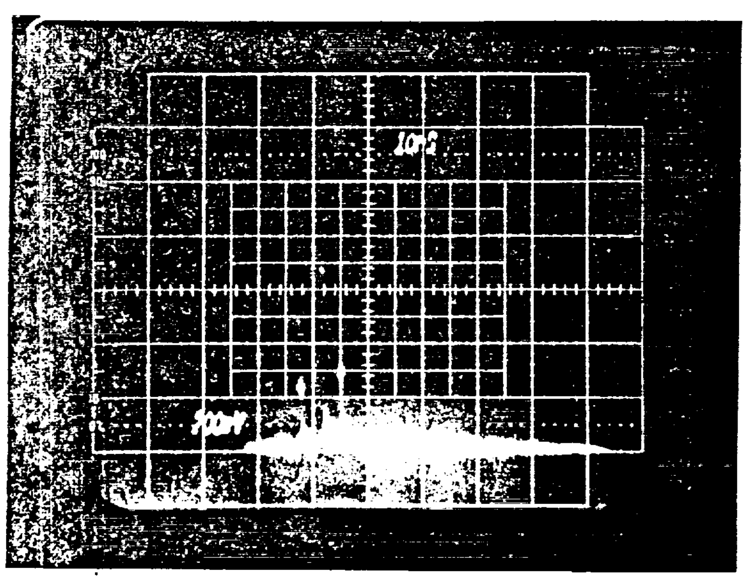

Fig.2 Oscillogram of the M-L pulse train

2. Theroy

Our experiment results exhibit that the mode-locked pulse train and pulse width have achieved compression simultaneously. This can't been explained fully by previous passively mode-locked theroy[1],[2]. Our study believe that true reasons for simultaneously compression should be altributed to the collision interference of the nonlinear ring interferometer, which formed a temporally modulated grating and stationary in space. Therefore, this grating is free from the deleterious atomic motionally induced or frequency-induced "washout" effect. Then, counterpropagation two beams, suffer strongly saturable absorption modulation, and at splitter mirror, again interference, resulting beams, which through a high inversion gain medium, the pulse signal obtain enhanced and compressed by cross-phase modulation. The necessary conditions of the doubly compression by using nonlinear ring interferometer, are Y1 parameter enough large, as that has to be at least one order of magnitude larger than R of [1]. $Y1 \sim |\ln \delta \Omega|$ is the initial amplitude of the stimulated emission, $\delta \Omega$ is solid angle, in which the laser radiation are concentrated. In according to [3], we deduced

$$Y1 = \left(\frac{\delta n}{n}\right)^2 \frac{TV(X1 + \mu_a)}{2\zeta}$$

here $\zeta$ is the relative excess pump power above the threshold for a closed shutter, $(\delta n / n)$ is the relative excess inversion population, T, cavity period time for mode-locked operation, $(X1 + \mu_a)$, X1 is the linear losses per unit optical path, $\mu_a$ is absorption coefficient of the mode-locking dye. $\mu_a$ must be enough large, as that has to be at least one order of magnitude larger than corresponding value of optimum transmittance of [2]. In proper conditions, sufficient large Y1 can be depleted the $\delta n$, and initiated the nonlinear ring interferometer, an overshoot pulse after switching[4], return to a high inversion gain medium, then the pulse signal enhanced and compressed by cross-phase modulation, simultaneously compression of the mode-locked pulses achieved quickly, and a single gaint pulse is obtained.

3. Experiment setup

Experiment setup used in this work is different to [4] slightly. The main difference are addition of interferometer's function.

The nonlinear ring interferometer is composed of a P-polarization 50/50 splitter 1, two totally reflective turning mirrors 2 and 3, and a dye cell 4, which located at the colliding center, fulling pentamethine cyanine dissolve in 1,2-dichloroethane. Two polarizers 5 and 10 used for enhance the polarization purity of the gain medium Nd:YAG, 6, 90mm in length and 6.0mm in diameter, the ends of the rod were angled at 87.5° to the normal of the rod axis. The rear reflector, 11 is a convex mirror, turning mirrors 7 and 8, an aperture 9, output coupled mirror 12 and recollimated lens 13.

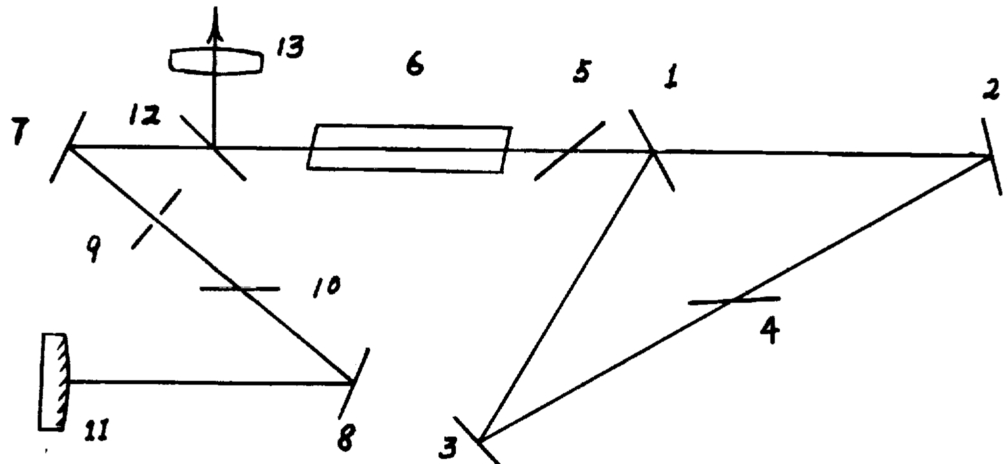


Fig.3 Optical layout of a nonlinear Sagnac ring interferometer.

Since the distance from the splitter mirror to colliding center is equal optical path, for all longitudinal modes $\omega_0 \pm m\Delta\omega$, that into oscillated, can be formed interference fringes, stabilzed in space, and thess fringes are insensitive to mechanical and thermal perturbation. Due to the high angle selectivity of this system, so that it may be maintaining good aligenement over days of operation. In this system do not need single pulse selector and A-O modulator, without any amplify, the output energy of oscillator can be achieved >30mJ, pulsewidth <10ps. These performances are sufficient for many applications. For as LAGEOS and ETALON ( 20,000KM ) satellite laser ranging, only need addition to one amplifier and a frequency doupler. More recently, the facts of successful laser ranging of LAGEOS and ETALON in Shanghai Observatory, have showed this point.

## 4. Conclusions

We have reported the results of a nonlinear Sagnac ring interferometer hybried unstable resonator. The results demonstate that the multiple interference effect quicken the mode-locking process, and the simultaneously compression of the mode-locked pulsewidth and pulse train have been achieved, and a GW level single pulse was obtained. This system have many advantages as that lighter weight, smaller size and insensitive to mechanical and thermal perturbations, particularly applied to outfield utilizations, such as mobile satellite laser ranging, and have great potentialities for heighten precision and distance of laser satellite ranging.

The damage problem of the optical components and improvement of the ratio of the first-second peak of the mode-locked train are currently in the progress.

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